U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

PI: **Franz-Josef Ulm** **Proposal No.: 99-0126**

Institution: **Massachusetts Institute of Technology**

Collaborators: **Commissariat 'L Energie Atomique**

Title: **Monitoring the Durability Performance of Concrete in Nuclear Waste Containment**

Concrete is commonly employed in radioactive waste disposal as an effective construction material for containment barriers, liners, and encasement of containers. However, research is necessary before a reliable application of concrete materials for hazardous waste containment is possible. Reliable application requires fundamental knowledge of the aging kinetics of concrete in the timespace scale of the waste storage.

The objective of the proposed research is to develop the scientific knowledge and the appropriate engineering tools required to evaluate and quantify the durability performance of Nuclear Waste concrete containment subjected to the pessimistic chemical degradation scenario of calcium leaching. Monitoring the durability performance means here the quantitative assessment, in time and space, of the integrity of the containment during the entire storage period. During the lifetime of the structure, it is generally assumed that concrete is subject to leaching by renewed deionized water. This leads to calcium leaching of Portlandite and C-S-H, to a degradation of the mechanical properties of concrete (material strength, Young's modulus), and to precipitation of ettringite; in turn, by swelling this expansive ettringite formation can lead to cracking which increases the calcium diffusion in the cracked material and accelerates the structural aging kinetics. Hence, monitoring the durability performance of concrete containment structures requires the consideration of the multiple couplings between diffusion-dissolution of calcium and deformation and cracking. To this end, a combined experiment a theoretical approach which will allow an extrapolation of laboratory test results to the field conditions of real-life concrete containment structures is necessary before confident application is possible.

The proposed research will focus on material modeling, computational mechanics, material and structural testing. First, fundamental analytical models that couple the diffusion-dissolution kinetics of calcium leaching with chemical damage, chemical decohesion and expansive ettringite formation will be developed. Then, experimental research will be conducted to determine the intrinsic material functions and parameters of clear physical significance and accessible by standard material tests. Implemented in a commercial finite element program, this model can be used in the future as an engineering prediction tool for diagnosis and life span evaluation of concrete containments.

The research will include the following tasks: (1) Development of a coupled diffusion-dissolution model for calcium leaching in uncracked and cracked concrete including the chemo-mechanical

couplings between calcium leaching and deformation and cracking; (2) Development of a sound computational mechanics approach which treats the coupled chemo-hydro-mechanical problem with implementation of the model in a commercial finite element program; (3) Material and structural testing with a focus on the experimental determination of (a) the intrinsic material functions of calcium leaching, (b) the structural effect of calcium leaching and ettringite formation on both structural load bearing capacity and structural eigenstresses in kinematically constrained structures (e.g., beams); and (4) application of the model to the durability analysis of real-life containment structures focusing on dimensional analysis in the time scale of structural chemical degradation.

This project which enters in the field of New Technologies for Management of Nuclear Waste, will benefit from the exchange and collaboration with the Commissariat a l'Energie Atomique (C.E.A.) in Saclay, France.